

Tuning luminescence of $\text{Ca}_9\text{La}(\text{PO}_4)_7:\text{Eu}^{2+}$ via artificially inducing potential luminescence centers

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Figure S1

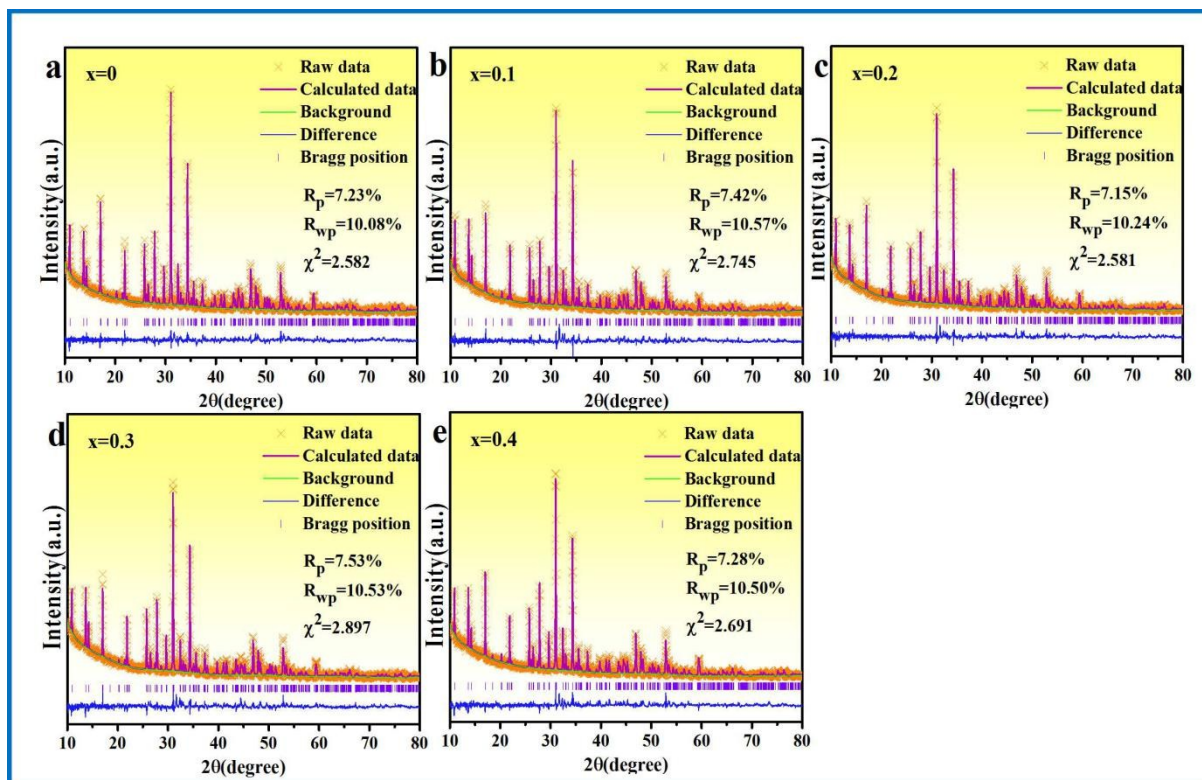


Fig. S1 Rietveld refinement results of $CL_{1-x}C_{1.5x}P:Eu^{2+}$ ($x=0, 0.1, 0.2, 0.3, 0.4$).

Table S1 Parameters of $CL_{1-x}C_{1.5x}P:Eu^{2+}$ ($x=0, 0.1, 0.2, 0.3, 0.4$) after Rietveld refinement.

| Formula | $x=0$ | $x=0.1$ | $x=0.2$ | $x=0.3$ | $x=0.4$ |
|-----------------------------------|-------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| 2θ (deg) | 10-80 | 10-80 | 10-80 | 10-80 | 10-80 |
| space group | R3c | R3c | R3c | R3c | R3c |
| a (Å) | 10.4877 | 10.4784 | 10.4749 | 10.4684 | 10.4634 |
| b (Å) | 10.4877 | 10.4784 | 10.4749 | 10.4684 | 10.4634 |
| c (Å) | 37.5831 | 37.5620 | 37.5546 | 37.5438 | 37.5311 |
| V (Å³) | 3580.041 | 3571.676 | 3568.594 | 3563.169 | 3558.510 |
| Z | 6 | 6 | 6 | 6 | 6 |
| R_p (%) | 7.23 | 7.42 | 7.15 | 7.53 | 7.28 |
| R_{wp} (%) | 10.08 | 10.57 | 10.24 | 10.53 | 10.5 |
| χ^2 | 2.582 | 2.745 | 2.581 | 2.879 | 2.691 |

Figure S2

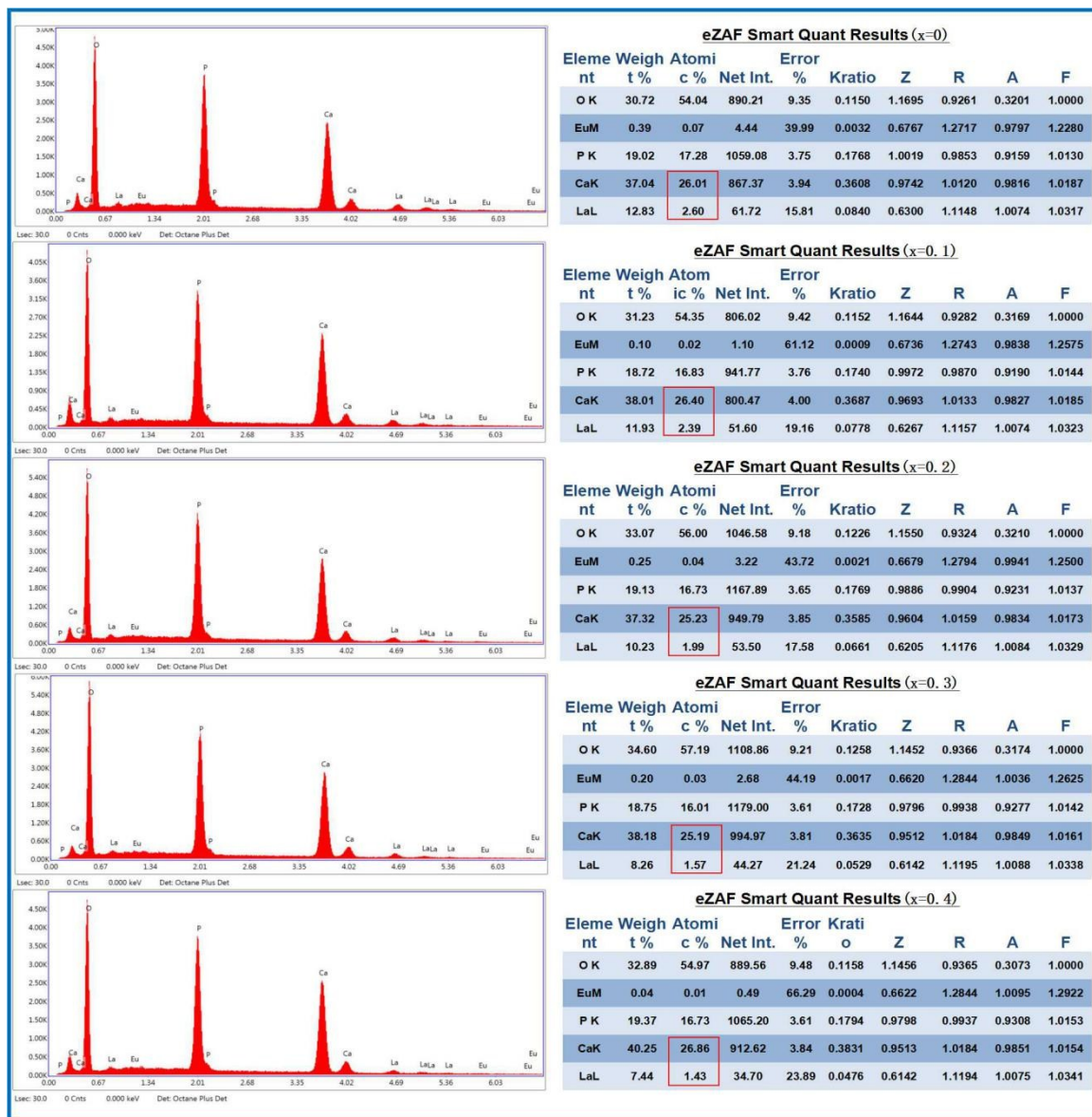


Fig.S2 EDS of $CL_{1-x}C_{1.5x}P:Eu^{2+}$ ($x=0, 0.1, 0.2, 0.3, 0.4$).

Figure S3

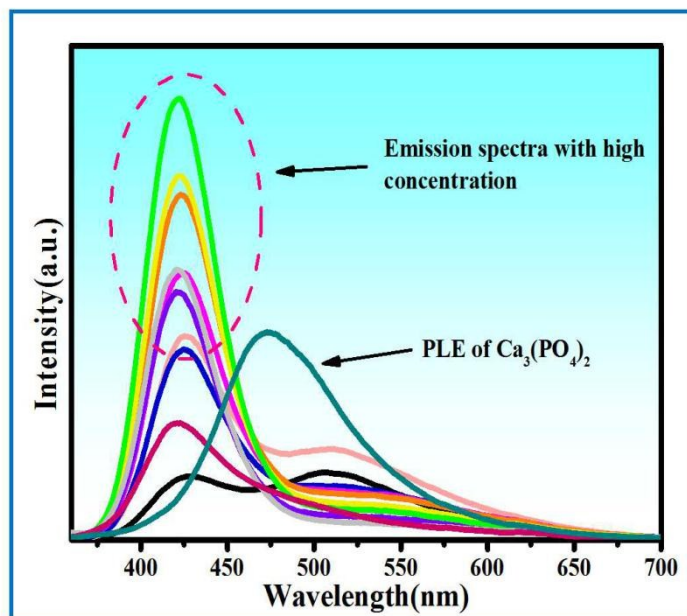


Fig. S3 Emission spectra of CLCP:Eu²⁺ with high concentration of doping inducible factor and Ca₃(PO₄)₂:Eu²⁺ under the same conditions.

Figure S4

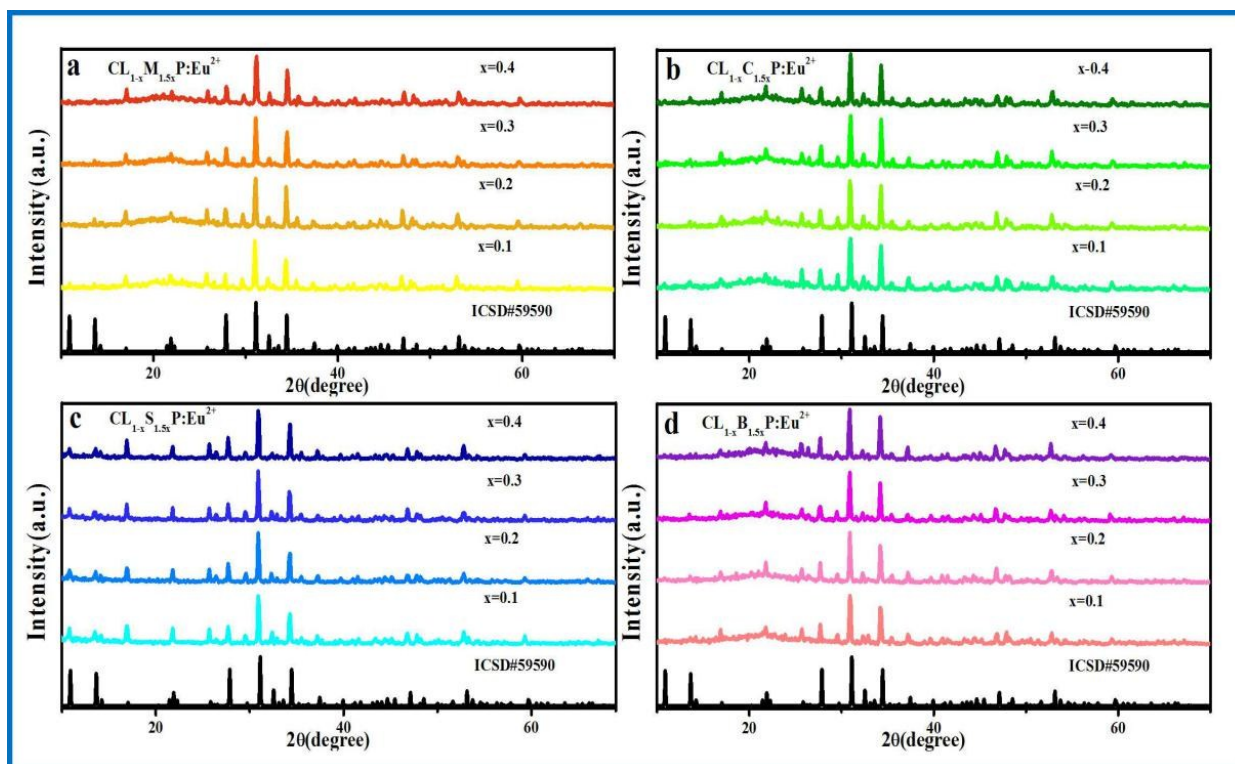


Fig.S4 XRD patterns of (a) $CL_{1-x}M_{1.5x}P:Eu^{2+}$, (b) $CL_{1-x}C_{1.5x}P:Eu^{2+}$, (c) $CL_{1-x}S_{1.5x}P:Eu^{2+}$ and (d) $CL_{1-x}B_{1.5x}P:Eu^{2+}$.

Figure S5

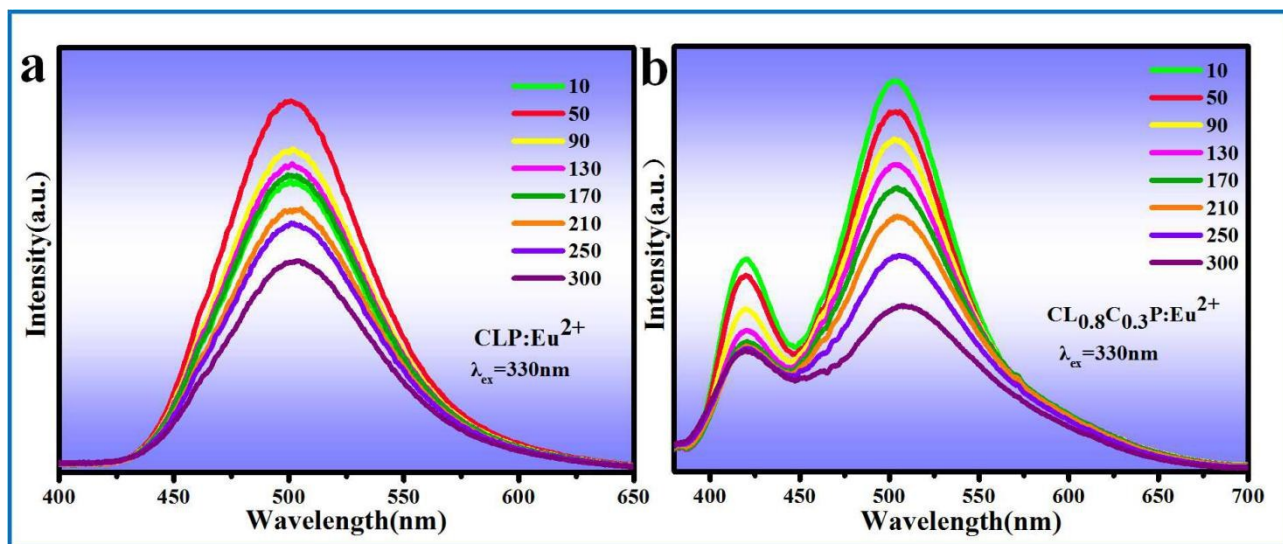


Fig. S5 Emission spectra of (a) CLP:Eu²⁺ and (b) CL_{1-x}C_{1.5x}P:Eu²⁺ ($x=0.2$) under 10k.

Figure S6

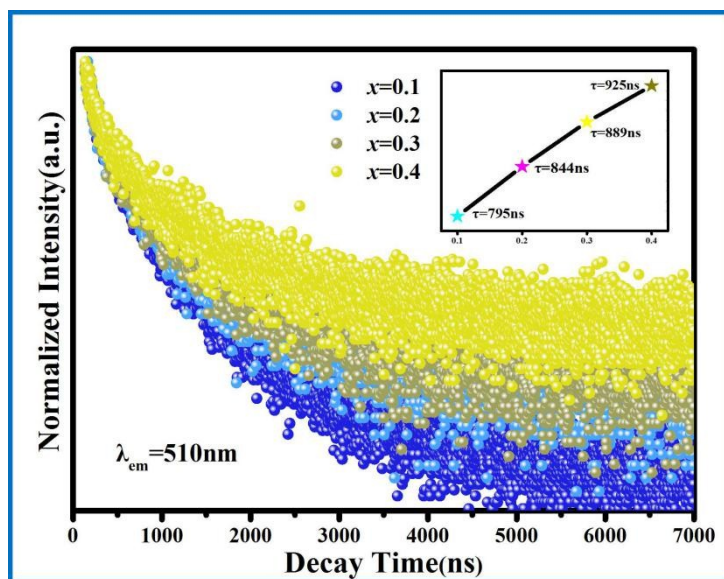


Fig. S6 Decay curves of the long-wave emission in CLP.

Inset: Lifetimes of the long-wave emission in CLP.

Figure S7

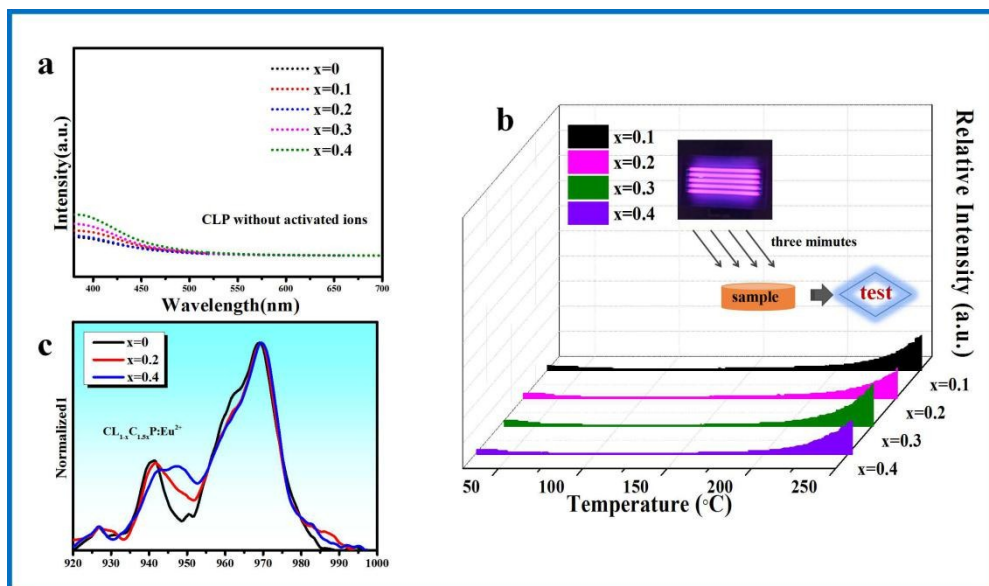


Fig. S7 (a) Emission spectra of CLCP without any activators. (b) TL spectra of $CL_{1-x}C_{1.5x}P:Eu^{2+}$ ($x = 0.1, 0.2, 0.3, 0.4$). (c) Intercepted Raman spectra of $CL_{1-x}C_{1.5x}P:Eu^{2+}$ ($x = 0, 0.2, 0.4$).

Figure S8

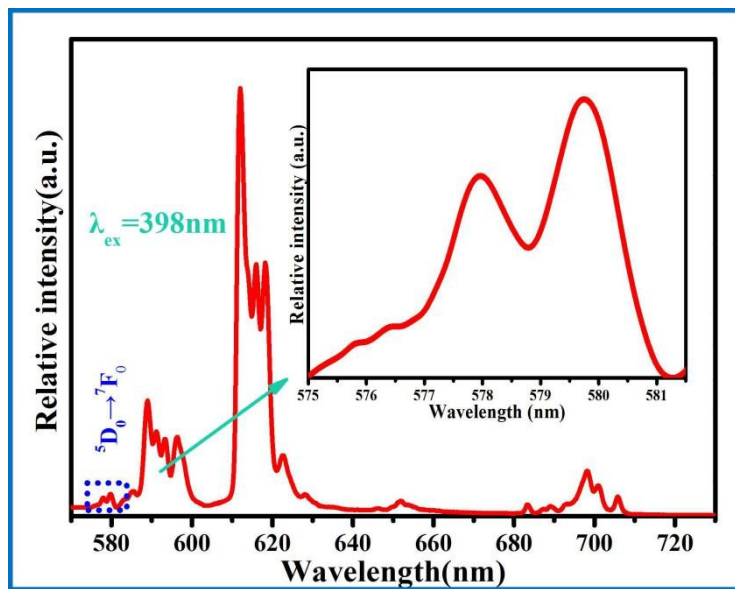


Fig. S8 High-resolution emission spectrum of $CL_{1-x}C_{1.5x}P:Eu^{3+}$ ($x = 0.2$).

Figure S9

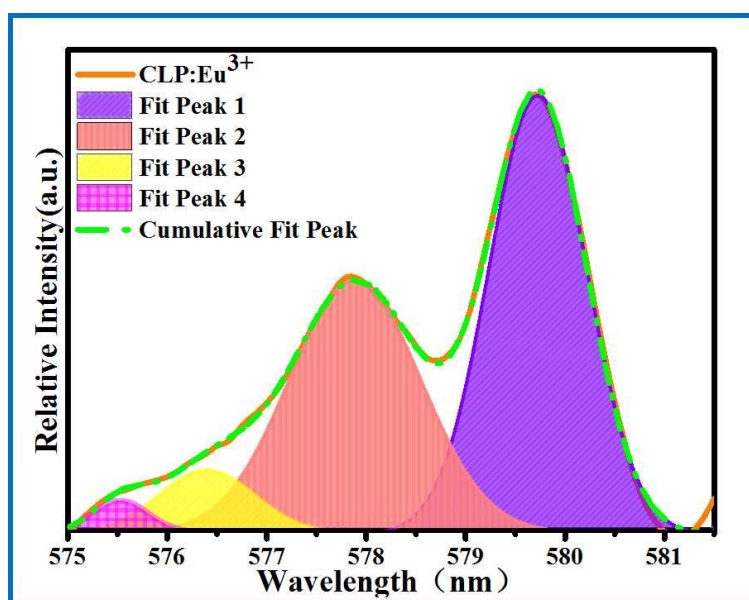


Fig. S9 High-resolution emission spectrum of ${}^5D_0 \rightarrow {}^7F_0$ transition for $CL_{1-x}C_{1.5x}P: Eu^{3+}$ ($x = 0$).

Figure S10

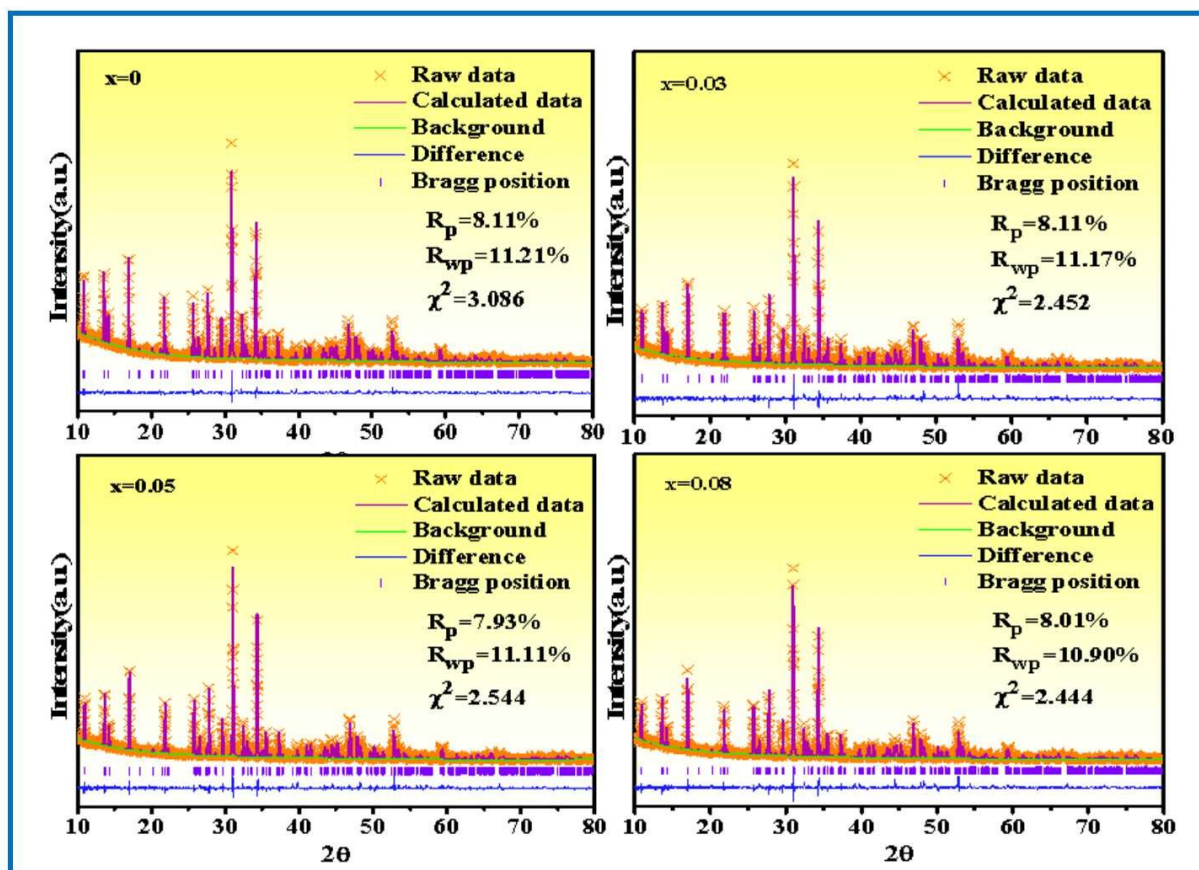


Fig. S10 Rietveld refinement results of CLP: $x\text{Eu}^{2+}$ ($x=0, 0.03, 0.05, 0.08$).

Figure S11

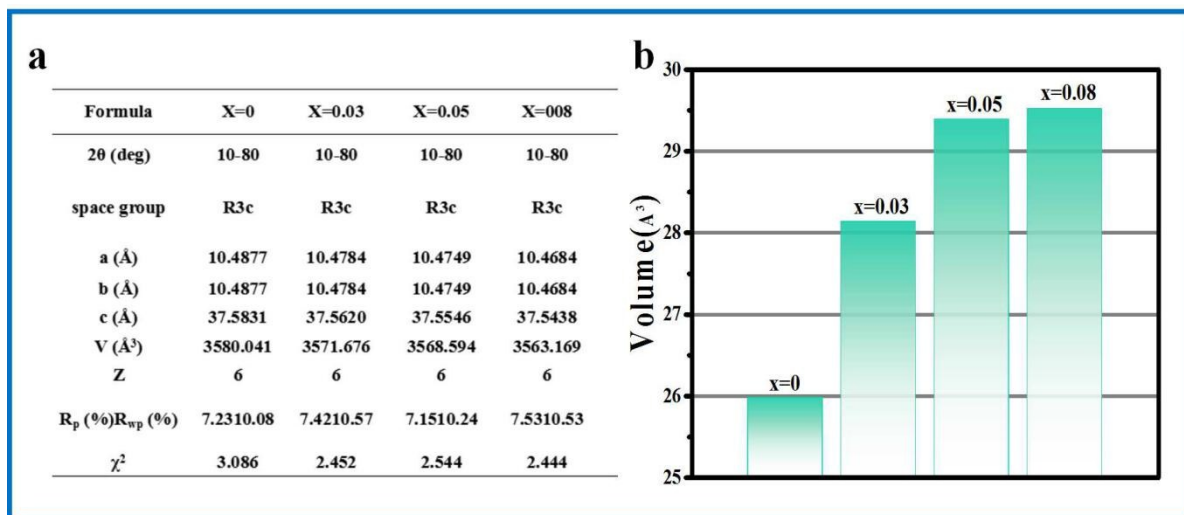


Fig. S11 (a) Parameters of CLP: $x\text{Eu}^{2+}$ ($x=0, 0.03, 0.05, 0.08$) after Rietveld refinement. (b) The volume of octahedron at the six-coordinate position.

Figure S12

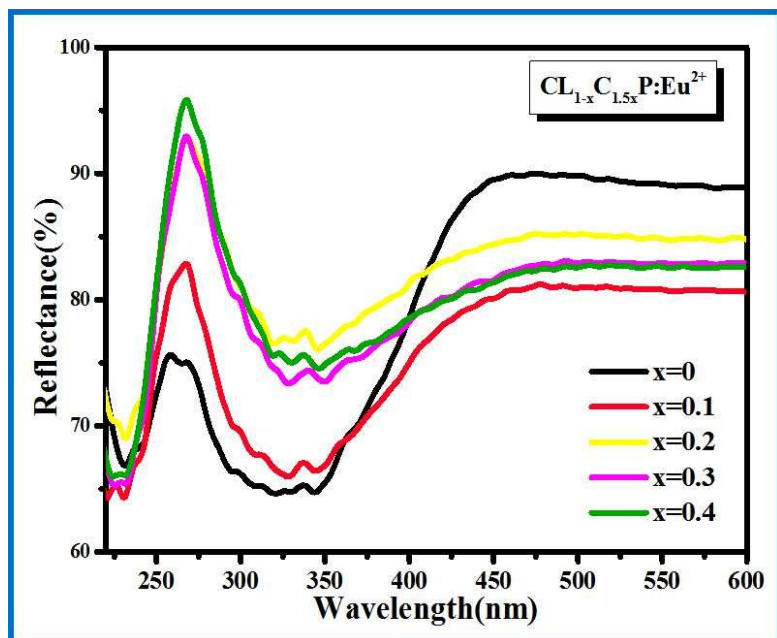


Fig.S12 Diffuse reflectance spectra of $CL_{1-x}C_{1.5x}P:Eu^{2+}$ ($x=0, 0.1, 0.2, 0.3, 0.4$).

Figure S13

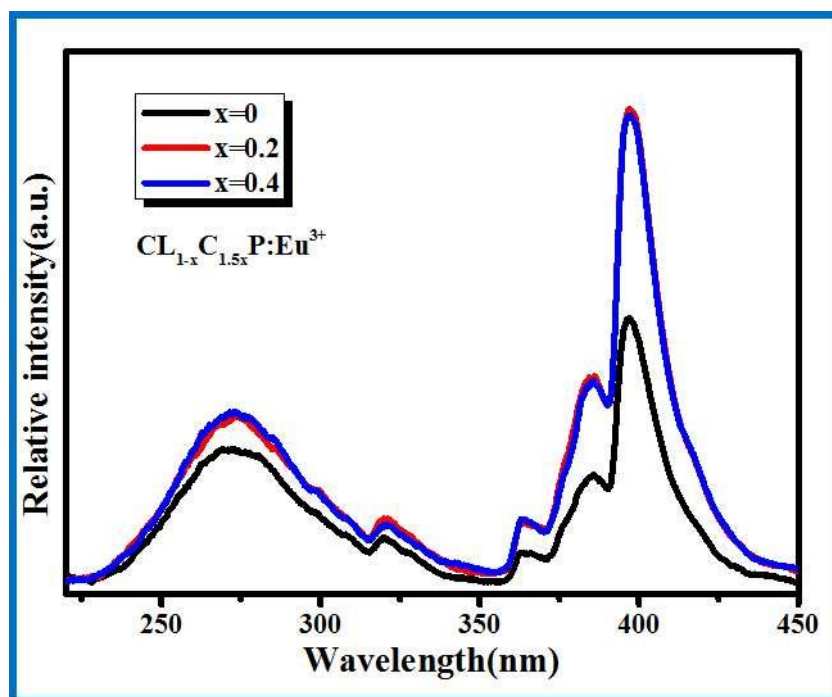


Fig.S13 Excitation spectra of $CL_{1-x}C_{1.5x}P:Eu^{3+}$ ($x=0, 0.1, 0.2$) ($\lambda_{em}=620nm$).

Figure S14

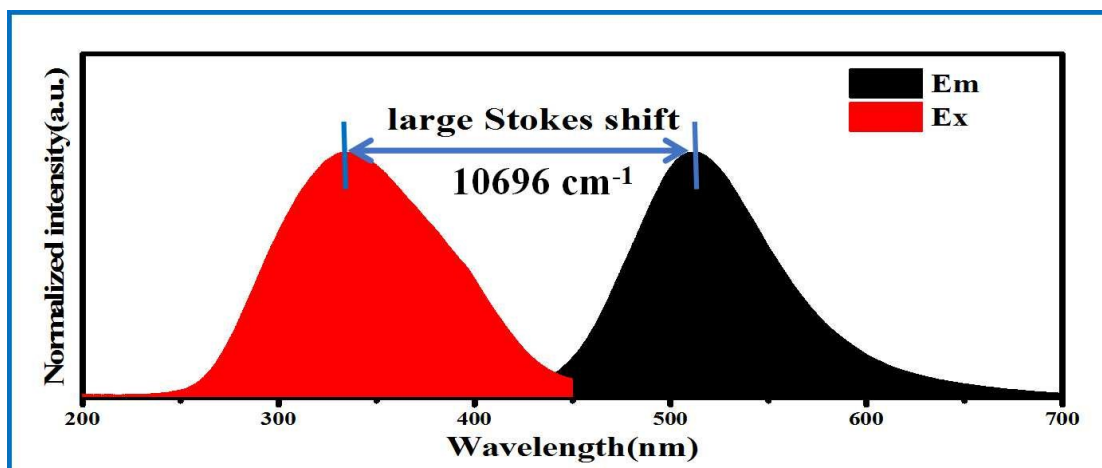


Fig. S14 Stokes shift of long-wave emission.

Figure S15

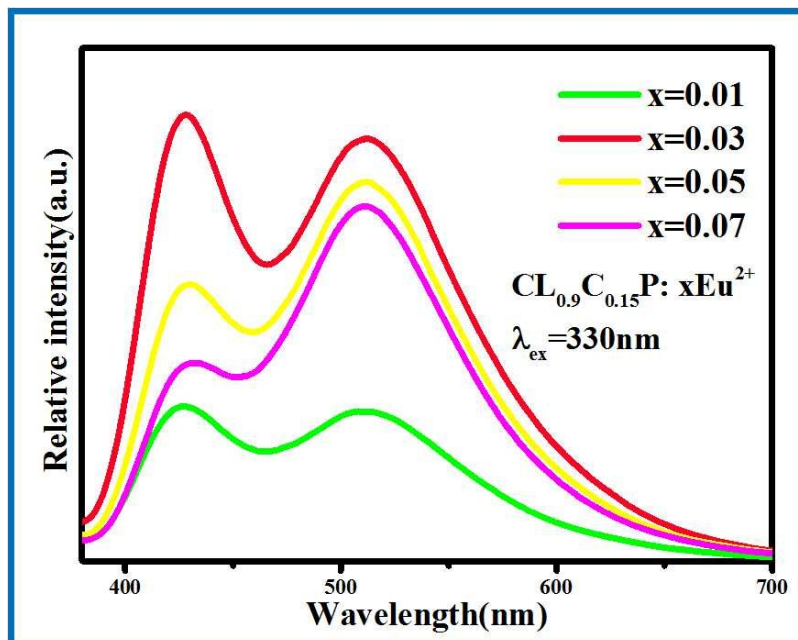


Fig. S15 Emission spectra of $\text{CL}_{0.9}\text{C}_{0.15}\text{P}:x\text{Eu}^{2+}$ ($x=0.01, 0.03, 0.05, 0.07$).